ORNL Technology for Laser-Based Ultrasonic Thickness Measurements

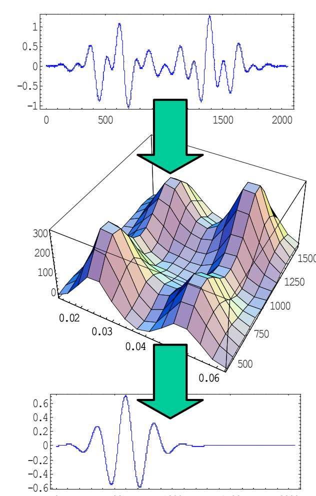
Signal Recovery

Ultrasonic Thickness Measurement

Over the course of three years Timken Incorporated conceived of a new non-contact method to measure wall thickness in seamless steel mechanical tubing. Failure to hold wall thickness to the specified dimension results in excess material that requires energy and effort to remove plus additional waste. Significant energy savings results from slight improvements in wall thickness measurement and subsequent process control actions. A measurement system was developed with Timken, Industrial Materials Institute of Canada, and ORNL based on laser ultrasonics. The concept is that a high-powered laser generates an ultrasonic "ping" on the metal surface and a second laser (interferometer) measures the time for the echo to return. The time lapse is representative of wall thickness. The system was designed to measure 100 points per second as the tube spins in the forming apparatus. The system has operated hundreds of hours with an expected level of maintenance. ORNL developed several relevant technical innovations.

Advanced Signal Processing

ORNL brought three advances in advanced signal processing to improve performance of laser based ultrasonic systems: high-speed processing with dedicated hardware, wavelet analysis, and Bayesian parameter estimation.



Bayesian Parameter Estimation

Compared to the conventional practice of cross correlation with a matched filter, Bayesian parameter estimation extracts more and better information from the data in a noisy signal. Matched filtering requires *a priori* knowledge of both the model and parameters of the desired signal, and has no capability for exploiting other prior knowledge. Bayesian parameter estimation requires only the model, and then provides an estimate of the desired parameter values, and a mathematical measure of the goodness of the measure (a confidence factor). If the noisy data include the desired signal plus undesired non-random signals, Bayesian will still reliably detect the desired signal; matched filters can be confused by unexpected non-random signals. Finally, Bayesian analysis can exploit prior information to improve the goodness of the estimate.

Compared to the conventional practice of split spectrum analysis (also known as Gabor analysis), wavelet analysis is computationally more efficient. The split spectra of Gabor analysis are non-orthogonal and their outputs are over determined; the resulting redundant data inherently imposes inefficiencies on the analysis process. In contrast, recently discovered wavelet algorithms produce orthogonal and critically sampled output data; these data represent information with the mathematically required minimum number of data points. Although the application of wavelets to LBU signatures was investigated a decade ago, most of the dramatic advances in wavelet analysis have been made since then, and it was appropriate to revisit the topic.

Features

- High-speed processing with dedicated hardware
- Wavelet analysis — fast signal matching and filtering
- Bayesian parameter estimation — precision estimation of model parameters

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